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APPARATUS AND METHOD FOR FORMING SINGLE CRYSTALLINE NITRIDE SUBSTRATE USING HYDRIDE VAPOR PHASE EPITAXY AND LASER BEAM

Description

Technical Field

The present invention relates to an apparatus and a method for making a single crystalline nitride substrate; and, more particularly, to an apparatus and a method for preventing cracks from being generated in a single crystalline nitride substrate.

Background Art

A GaN single crystalline substrate, as an example of a single crystalline nitride substrate, will be described. Generally, the GaN materials has a melting point more than of 2400 ℃ and the dissociation pressure of nitride in the GaN materials is about ten thousand atm. Accordingly, this high melting point and high dissociation pressure make it impossible to create a large single crystalline GaN bulk using typical growing methods of the semiconductor crystals. A needle-shaped crystal growing method, in which a gallium gas directly reacts on an ammonia gas at a high temperature of about 1000 ℃ to 1150 ℃, and a plate-shaped crystal growing method, in which nitrogen is dissolved in liquid gallium at a

high temperature of about 1500 ℃ to 1600 ℃ and at a high nitrogen pressure corresponding to about 20000 atm, has been used to create a single crystalline GaN bulk (hereinafter, referred to as a GaN bulk).

However, these crystal growth methods have made a small-sized GaN bulk which has only a few millimeters in size and about 100 μm in thickness. Accordingly, it is impossible to achieve a commercial success in using the GaN bulk.

To solve the above problem, a hydride vapor phase epitaxy has been used to create the GaN bulk at a growing rate of 100 μm/hour. That is, after forming a thick GaN film on a parent substrate, such as sapphire or SiC substrate, the parent substrate is removed and then the GaN bulk is finally formed.

The removal of the parent substrate is carried out by the mechanical polishing method or laser beam. In particular to laser, as shown in Fig. 1, after forming the thick GaN film on the parent substrate at a high temperature of about 1000 ℃ to 1100 ℃, the thick GaN film on the parent substrate is cooled down to a room temperature. After increasing the temperature of the parent substrate up to about 600 ℃, the thick GaN film is separated from the parent substrate using laser beam in an additional apparatus different from the hydride vapor phase epitaxy ("Large free-standing GaN substrate by hydride vapor phase epitaxy and laser induced lift-off," by K. Kelly et al, Jpn. J. Appl. Phys. Vol. 38, No.

3A (pt 2), 1999).

In the above-mentioned hydride vapor phase epitaxy, since the thick GaN film is formed on the sapphire substrate at a high temperature and it is cooled down to the room temperature, cracks are generated by the lattice mismatch and thermal expansion coefficients between the GaN film and the sapphire substrate. Because of these cracks, the GaN bulk is restricted within a small-sized substrate and electric characteristics therein are also deteriorated.

<u>Disclosure of Invention</u>

It is, therefore, an object of the present invention to provide an apparatus and a method for preventing cracks from being generated in a single crystalline nitride substrate which is made by a hydride vapor phase epitaxy method.

Another object of the present invention is to provide an apparatus and a method for forming a large single crystalline nitride substrate on a commercial basis.

In accordance with an aspect of the present invention, there is provided an apparatus for forming a compound semiconductor substrate, the apparatus comprising: a reacting chamber for forming a single crystalline film on a parent substrate; a heating chamber connected to the reacting chamber within a processing channel, wherein the single crystalline film is separated from the parent substrate at a higher temperature than a room temperature; and a supporter for supporting the single crystalline film and the parent

substrate and maintaining the single crystalline film in a predetermined temperature.

In accordance with another aspect of the present invention, there is provided a method for forming a compound semiconductor substrate, the method comprising the steps of: a) preparing a parent substrate; b) forming a single crystalline film on the parent substrate in a reacting chamber; c) maintaining the single crystalline film in a predetermined temperature which is higher than a room temperature; and d) illuminating laser beam on a backside of the parent substrate and separating the single crystalline film from the parent substrate.

According to the present invention, a thick GaN film is formed on a parent substrate, such as sapphire (Al_2O_3), spinel ($MgAl_2O_4$) or silicon carbide (SiC), which has the lattice mismatch with the single crystalline GaN film and a different thermal expansion coefficient, and the parent substrate is heated up to a range of 600 ℃ to 1000 ℃. In this temperature range, the single crystalline GaN film is separated from the parent substrate by laser beam.

Brief Description of Drawings

The above and other objects and features of the present invention will become apparent from the following description of preferred embodiments taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a plot illustrating a temperature variation in

a conventional method for forming a single crystalline nitride substrate;

Fig. 2 is a plot illustrating a temperature variation in a method for forming a single crystalline nitride substrate according to the present invention;

Fig. 3 is a schematic cross-sectional view of an apparatus for forming a single crystalline nitride substrate according to the present invention; and

Figs. 4A to 4D are schematic cross-sectional views illustrating a method for forming a single crystalline nitride substrate according to the present invention.

Best Mode for Carrying out the Invention

Referring to Fig. 3, a horizontality-type hydride vapor phase epitaxy apparatus of an atmospheric pressure is shown in order to form a single crystalline nitride substrate. The hydride vapor phase epitaxy apparatus includes a reacting chamber 11A in which a quartz boat (not shown) is placed, a heating chamber 11C having a supporter 40 to maintain a specimen, and an exhausting chamber 11B positioned between the reacting chamber 11A and the heating chamber 11C and coupled to an exhausting system 16. The temperature of the supporter 40 in the heating chamber 11C is maintained in a specific temperature range and laser beam illumination to separate a single crystalline nitride film from a parent substrate 30 is carried out in the heating chamber 11C. Further, each of the chambers 11A to 11C adjacent to the exhausting chamber 11B is

sealed up with shutters 12 and flanges 12A are mounted on both ends of the chambers 11A and 11C.

The reacting chamber 11A is surrounded by a multi-step electric furnace 13 and is connected to a first inlet to supply an ammonia gas and a second inlet to supply hydrochloric acid and nitrogen gases. These gases react on Ga materials 20 within the reacting chamber 11A and then a thick GaN film is deposited on the parent substrate 30 adjacent to the Ga materials 20. While the thick GaN film is grown in the reacting chamber 11A, the reacting gases are purged away through the exhausting system 16 in the exhausting chamber 11B and when the growth of the single crystalline nitride substrate (the thick GaN film) has been finished, the reacting chamber 11A is isolated from the exhausting chamber 11B by the shatter 12. The parent substrate 30 on which the thick GaN film is formed is removed onto the supporter 40 in the heating chamber 11C without being exposing to air and laser beam is illuminated on the backside of the parent substrate 30 at a temperature of about 600 ℃ to 1000 ℃ to separate a single crystalline GaN film (thick GaN film) from the parent substrate 30. It should be noted that the thick GaN film and the parent substrate 30 are not cooled down to a room temperature.

Although the exhausting chamber 11B, as shown in Fig. 3, is positioned between the reacting chamber 11A and the heating chamber 11C, the reacting chamber 11A may be adjacent to the heating chamber 11C and the exhausting system 16 may be

directly connected to the reacting chamber 11A.

The hydride vapor phase epitaxy apparatus shown in Fig. 3 may be used to form group Ⅲ-N (nitrogen) compounds of single crystalline substrates, such as AlN, InN, GaInN, AlInN and AlGaInN, as well as the GaN single crystalline substrate, containers having Ga and In materials may be provided in the reacting chamber 11A and the hydrochloric acid and nitrogen gases flow into the reacting chamber 11A.

Figs. 4A to 4D illustrate a method for forming the GaN single crystalline substrate.

First, referring to Fig. 4A, the parent substrate 30 selected from one of an oxide substrate, such as sapphire (Al_2O_3) or spinel ($MgAl_2O_4$), and a silicon carbide substrate, such as SiC, is prepared and generally these parent substrates may have the lattice mismatch with the GaN materials and a different thermal expansion coefficient.

Next, referring to Fig. 4B, the thick GaN film 31 is formed on the parent substrate 30 in the hydride vapor phase epitaxy apparatus, as shown in Fig. 3, having the quartz boat in its reacting chamber 11A and the supporter 40 in its heating chamber 11C. The group Ⅲ elements such as Ga are positioned at a region which is maintained at a temperature of about 600 ℃ to 900 ℃ by the multi-step electric furnace 13. At this time, the parent substrate is maintained at a temperature of about 1000 ℃ to 1100 ℃. The reacting chamber 11A in which the quartz boat is placed is pumped out up to

about 10-3 torr, the reacting chamber 11A is gradually heated, and then the nitrogen gas injection into the reacting chamber 11A starts from about 600 ℃. When the reacting chamber 11A reaches to a temperature at which the thick GaN film is to be grown, the hydrochloric acid gas flows onto the Ga materials in the quartz boat and the ammonia gas is provided to the parent substrate 30 to form the thick GaN film 31 on the parent substrate 30 at a thickness of about 100 μm to 550 μm.

After forming the thick GaN film 31 on the parent substrate 30, the supply of the hydrochloric acid gas is broken off and the parent substrate 30 on which the thick GaN film 31 is formed is cooled with the supply of nitrogen and the ammonia gases until the temperature of the thick GaN film 31 reaches to a predetermined temperature range, e.g., about 600 ℃ to 1000 ℃.

Referring to Fig. 4C, when the temperature of the reacting chamber 11A reaches to 600 ℃ to 1000 ℃, the parent substrate 30 on which the thick GaN film 31 is formed is moved onto the supporter 40 in the heating chamber 11C. At this time, the temperature of supporter 40 is maintained at about 600 ℃ to 1000 ℃ and the bottom of the parent substrate 30 is turned over top so that the thick GaN film 31 is directly on the supporter 40. The turned upside of the parent substrate 30 is illuminated by laser beam. It should be noted that the thick GaN film 31 and the parent substrate 30 are not cooled down to a room temperature.

Referring to Fig. 4D, the parent substrate 30 is separated from the thick GaN film 31 by the high power laser beam. Nd:YAG laser beam, which has wavelength of 355 nm, power of about 500 mJ, pulse period of 10 to 20 Hz and pulse width of 5 to 6 ns, may be used. When this high power laser beam is illuminated on the parent substrate 30, the beam passes through the parent substrate 30 and is absorbed into the thick GaN film 31. If the thick GaN film 31 absorbs the high power laser beam, the GaN material, which is in a range of a few micrometers in thickness (dissolution area 32), are dissolved into gallium and nitrogen and the thick GaN film 31 is separated from the parent substrate 30 by this dissolution of the thick GaN film 31.

Since the single crystalline GaN substrate (the separated thick GaN film 31A has an uneven surface, the mechanical and chemical polishing using a diamond slurry is applied to the single crystalline GaN substrate 31A.

As apparent from the above, the present invention provides a high growing rate of the single crystalline nitride substrate without cracks caused by the lattice mismatch between other materials, by using the hydride vapor phase epitaxy method. Furthermore, the present invention provides stability and reliability of processing by effectively separating the single crystalline nitride substrate from the parent substrate by laser beam.

Although the preferred embodiments of the invention have been disclosed for illustrative purposes, those skilled in the

art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.